FORM 2
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COMPLETE SPECIFICATION
(See section 10 and rule 13)

1. TITLE OF THE INVENTION

DEPLOYABLE BOOM ASSEMBLY

2. APPLICANT:

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification particularly describes the invention and the manner in which it is to be performed.

FIELD OF THE INVENTION

The present disclosure discloses a deployable boom assembly for spacecraft applications. More particularly, the present disclosure discloses a deployable boom assembly with a deployment unit for coordinated deployment of a plurality of boom segments.

BACKGROUND

Generally, a spacecraft employs various elements/payloads for example, reflectors, antenna arrays, sensors etc. to perform different specific functions from space. These elements have to be deployed away from the body of the spacecraft such that the components are protected from any kind of probable interference from the body of the spacecraft. Thus, deployable structures, especially a deployable boom assembly, helps in holding these elements, away from the body of the spacecraft in the space. This avoids any electrical disturbance caused by remanence of the body of the spacecraft. Further, the deployable boom segment assembly includes plurality of boom segments, where a coordinated and predictable movement of the plurality of boom segments are essential for complete deployment of the boom. This facilitates correct positioning of the elements on the plurality of boom segments. Moreover, coordinated opening of the boom from the plurality of boom segments ensures a lower deployment latch up moment and also ensures simpler ground test equipment. However, the spacecraft launcher imposes constraints on the boom from the plurality of boom segments withstanding launch loads and being accommodatable in a limited launcher envelope. Hence, there is a constant need to provide for a light weighted deployable boom assembly having a compact folded structure, with provision to transfer and withstand the launch loads and fit into the launcher envelope.

In this regard, different types of the deployable boom assembly are developed, for example, a hinged type deployable boom assembly, a liner type deployable boom assembly, a Rollable type deployable boom assembly, a segmented boom type deployable boom assembly etc. The Rollable type deployable boom assembly does not provide provision for accommodating payloads at different location of the plurality of booms. Further, the segmented type deployable boom assembly discloses a configuration which leads to uncontrolled opening of the plurality of boom segments. Further, in some cases, the segmented type deployable boom assembly includes a controlled opening of the plurality of boom segments through an active motorized system. However, the configuration of the controlled opening of the plurality of boom segments has a complex and voluminous structure leading to increased assembly, manufacturing time and greater demand of electrical resources. Further, the configuration also requires an additional component to facilitate controlled opening of the plurality of boom segments.

Further, the hinged type deployable boom assembly includes a plurality of hinges mounted with a drive pulley and a driven pulley, individually, to connect the plurality of boom segments with each other. The configuration discloses various types of plurality of hinges, for example, a tape spring-based hinges with linkage mechanism for compact storing. However, this configuration leads to non-coordinated opening of the plurality of boom segments leading to haphazard opening of the plurality of boom segments thus impacting the predictability of link positions during opening. This leads to complicated ground system design for demonstrating its function on ground by simulating the in-orbit conditions. This also leads to various scenario-based latch up shock and deployment sequences, when deployed on-orbit.

Another known art discloses a plurality of hinges acting as a drive pulley and a driven pulley, individually, having a linkage mechanism for coordinated opening of a plurality of boom segments. Further the plurality of hinges facilitates

deployment of the plurality of boom segments in the space. So, when the spacecraft is in the space, these hinges assist or rotate the boom assembly from the stowed position to the deployed position to position the elements in the space. However, this configuration has its own disadvantages as the configuration as disclosed has complex wire routing near joints of plurality of hinges, making configuration complex, also increases transmission losses, high resistive torque, increased number of components etc. Further, the configuration having plurality of hinges with the pulley lanyard system have complex routing and use SS wire rope-based configuration. These configurations are not suitable for deploying magnetically sensitive payload in the space.

Hence, there is a need of a deployment unit to deploy the plurality of boom segments while addressing the aforementioned problem.

SUMMARY

This summary is provided to introduce a selection of concepts, in a simplified format, that are further described in the detailed description of the invention. This summary is neither intended to identify key or essential inventive concepts of the invention and nor is it intended for determining the scope of the invention.

The aim of the present disclosure is to provide a deployment unit to deploy a plurality of boom segments, while reducing resistive torque and facilitating controlled and co-ordinated deployment of the plurality of boom segments with reduced number of components.

In an embodiment, a deployable boom assembly for a space bound object is disclosed. The deployable boom assembly comprising a plurality of supporting members, a plurality of boom segments, a deployment unit. The plurality of boom segments is supported on the plurality of supporting members. The space bound object is attached on the plurality of boom segments. The deployment unit is

adapted to move each of the plurality of boom segments. The each of the plurality of boom segments moves between a retracted position and an extended position. The deployment unit comprising a plurality of hinges and a plurality of transmission members. The plurality of hinges is disposed between the plurality of boom segments. The plurality of hinges is adapted to enable relative movement between each of the plurality of boom segments disposed adjacently and subsequently with each other. The plurality of transmission members is supported on the plurality of hinges. The plurality of transmission members is movably disposed between the plurality of boom segments. Each of the plurality of transmission members is adapted to be driven by one of the plurality of boom segments and is adapted to drive adjoining boom segment from the plurality of boom segments. The adjoining boom segments from the plurality of boom segments is disposed adjacently and subsequently, between the retracted position and the extended position.

According to the present disclosure, the deployable boom assembly as disclosed ensures mounting of plurality of space bound object, for example, payloads. The present configuration also ensures coordinated near accordion deployment. Further, the present configuration ensures that energy is shared across the plurality of transmission lines. Further, the present invention also ensures reduced resistive wiring torque during the deployment of the plurality of boom segments.

To further clarify advantages and features of the present disclosure, a more particular description of the invention will be rendered by reference to specific embodiments thereof, which is illustrated in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

Figure 1A illustrates an assembled view of a deployable boom assembly, in accordance with an embodiment of the present disclosure;

Figure 1B illustrates a bottom view of the deployable boom assembly, in accordance with an embodiment of the present disclosure;

Figure 1C illustrates an isometric view of the deployable boom assembly with a wiring routing, in accordance with an embodiment of the present disclosure;

Figure 2A illustrates a bottom view of the deployable boom assembly with a deployment unit, in accordance with an embodiment of the present disclosure;

Figure 2B illustrates a perspective view of the deployment unit with a plurality of hinges and an elastic member, in accordance with an embodiment of the present disclosure;

Figure 2C illustrates a perspective view of the deployment unit, in accordance with an embodiment of the present disclosure;

Figure 2D illustrates a bottom view of the deployable boom assembly with a monitoring and correction mechanism, in accordance with an embodiment of the present invention;

Figure 2E (a) illustrates the deployable boom assembly in partially deployed condition, in accordance with an embodiment of the present disclosure;

Figure 2E (b) illustrates the deployable boom assembly in fully deployed condition, in accordance with an embodiment of the present disclosure; and

Figure 2F illustrates a side view of the hinge bracket with a pawl and cam latch mechanism, in accordance with an embodiment of the present invention.

Further, skilled artisans will appreciate that elements in the drawings are illustrated for simplicity and may not have necessarily been drawn to scale. Furthermore, in terms of the construction of the device, one or more components of the device may have been represented in the drawings by conventional symbols, and the drawings may show only those specific details that are pertinent to understanding the embodiments of the present disclosure so as not to obscure the drawings with details that will be readily apparent to those of ordinary skill in the art having benefit of the description herein.

DETAILED DESCRIPTION OF FIGURES

For the purpose of promoting an understanding of the principles of the invention, reference will now be made to the embodiment illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is thereby intended, such alterations and further modifications in the illustrated system, and such further applications of the principles of the invention as illustrated therein being contemplated as would normally occur to one skilled in the art to which the invention relates. Unless otherwise defined, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skilled in the art to which invention belongs. The system and examples provided herein are illustrative only and not intended to be limiting.

It should be appreciated by a person skilled in the art that the terminology and structure employed herein is for describing, teaching, and illuminating some embodiments and their specific features and elements and therefore, should not be construed to limit, restrict or reduce the spirit and scope of the present disclosure in any way.

For example, any terms used herein such as, “includes,” “comprises,” “has,” “consists,” and similar grammatical variants do not specify an exact limitation or restriction, and certainly do not exclude the possible addition of one or more features or elements, unless otherwise stated. Further, such terms must not be taken to exclude the possible removal of one or more of the listed features and elements, unless otherwise stated, for example, by using the limiting language including, but not limited to, “must comprise” or “needs to include.”

Whether or not a certain feature or element was limited to being used only once, it may still be referred to as “one or more features” or “one or more elements” or “at least one feature” or “at least one element.” Furthermore, the use of the terms “one or more” or “at least one” feature or element do not preclude there being none of that feature or element, unless otherwise specified by limiting language including, but not limited to, “there needs to be one or more...” or “one or more elements is required.”

Unless otherwise defined, all terms and especially any technical and/or scientific terms, used herein may be taken to have the same meaning as commonly understood by a person ordinarily skilled in the art.

Reference is made herein to some “embodiments.” It should be understood that as per one embodiment is an example of a possible implementation of any features and/or elements of the present disclosure. Some embodiments have been described for the purpose of explaining one or more of the potential ways in which

the specific features and/or elements of the proposed disclosure fulfil the requirements of uniqueness, utility, and non-obviousness.

Use of the phrases and/or terms including, but not limited to, “a first embodiment,” “a further embodiment,” “an alternate embodiment,” “one embodiment,” “an embodiment,” “multiple embodiments,” “some embodiments,” “other embodiments,” “further embodiment”, “furthermore embodiment”, “additional embodiment” or other variants thereof do not necessarily refer to the same embodiments. Unless otherwise specified, one or more particular features and/or elements described in connection with one or more embodiments may be found in one embodiment, or may be found in more than one embodiment, or may be found in all embodiments, or may be found in no embodiments. Although one or more features and/or elements may be described herein in the context of only a single embodiment, or in the context of more than one embodiment, or in the context of all embodiments, the features and/or elements may instead be provided separately or in any appropriate combination or not at all. Conversely, any features and/or elements described in the context of separate embodiments may alternatively be realized as existing together in the context of a single embodiment.

Any particular and all details set forth herein are used in the context of some embodiments and therefore should not necessarily be taken as limiting factors to the proposed disclosure.

Embodiments of the present disclosure will be described below in detail with reference to the accompanying drawings.

For the sake of clarity, the first digit of a reference numeral of each component of the present disclosure is indicative of the Figure number, in which the corresponding component is shown. For example, reference numerals starting with

digit “1” are shown at least in Figure 1. Similarly, reference numerals starting with digit “2” are shown at least in Figure 2.

Figure 1A illustrates an assembled view of a deployable boom assembly 100, in accordance with an embodiment of the present disclosure. **Figure 1B** illustrates a bottom view of the deployable boom assembly 100, in accordance with an embodiment of the present disclosure. **Figure 1C** illustrates an isometric view of the deployable boom assembly 100 with a wiring routing 106, in accordance with an embodiment of the present disclosure. **Figure 2A** illustrates a bottom view of the deployable boom assembly 100 with a deployment unit 202, in accordance with an embodiment of the present disclosure. **Figure 2B** illustrates a perspective view of the deployment unit 202 with a plurality of hinges 203 and an elastic member 207, in accordance with an embodiment of the present disclosure**. Figure 2C** illustrates a perspective view of the deployment unit 202, in accordance with an embodiment of the present disclosure. **Figure 2D** illustrates a bottom view of the deployable boom assembly 100 with a monitoring and correction mechanism 208, in accordance with an embodiment of the present invention. **Figure 2E (a)** illustrates the deployable boom assembly 100 in partially deployed condition, in accordance with an embodiment of the present disclosure. **Figure 2E (b)** illustrates the deployable boom assembly in fully deployed condition, in accordance with an embodiment of the present invention. **Figure 2F** illustrates a side view of the plurality of hinges 203 with a pawl and cam latch mechanism 206, in accordance with an embodiment of the present invention. The deployable boom assembly 100 is used for deploying a space bound object, for example, a plurality of payloads 101 in a space from a spacecraft. The deployable boom assembly 100 with the deployment unit 202 disclosed in the present disclosure ensures efficient working of the deployment boom assembly 100 with reduced number of components, reduced resistive torque etc.

The deployable boom assembly 100 for the space bound object comprises a plurality of supporting members 100, a plurality of boom segments 102 supported

on the plurality of supporting members 103. The space bound object, for example, a plurality of payloads 101 are attached on the plurality of boom segments 102, the deployment unit 202 (as shown in Figure 2B) to move each of the plurality of boom segments 102 between a retracted position and an extended position, a plurality of wire routing 105, the monitoring and correction mechanism 208 (as shown in Figure 2E) among other examples, details of which will be provided in subsequent paragraphs.

Referring to Figure 1A-1C, the plurality of boom segments 102 is stowed on the plurality of supporting members 103, in a compact manner. The plurality of boom segments 102 includes a first boom segment 102a, a second boom segment 102b, a third boom segment 102c, a fourth boom segment 102d, a fifth boom segment 102e. The first boom segment 102a is smaller than the adjoining boom segments 102b, 102c, 102d, 102e. Further, each of the boom segment from the plurality of boom segments 102 are attached with each other through the deployment unit 202 (as shown in Figure 2B) and the plurality of wire routing 105. The deployment unit 202 and the plurality of wire routing 105 are provided at the bottom side of the plurality of boom segments 102. The plurality of wire routing 105 includes a wire routing 105a, a wire routing 105b, a wire routing 105c and a wire routing 105d. The wire routings 105a-105d along with the deployment unit 202 facilitates movement of each of the boom segment from the plurality of boom segments 102 in a retracted and an extended position.

In one example, the plurality of payloads 101 is a magnetometer sensor. The plurality of payloads 101 is disposed on an upper side of the plurality of boom segments 102. The plurality of payloads 101 is disposed at a predefined distance with each other on the plurality of boom segments 102. The plurality of boom segments 102 is magnetically clean which enables deployment of the plurality of payloads 101 on the plurality of boom segments 102in the space, and in an orbit of an earth. The plurality of payloads 101 is deployed in the orbit of the earth through the retraction and the extension of the plurality of boom segments 102. Further, the

plurality of payloads 101 includes a plurality of wiring routing 106, where the wiring routing 106 includes a payload wire, a thermal wire and a telemetry wire. The plurality of wiring routing 106 is installed on the upper side of the plurality of boom segments 102 and interfaces with a connector present in the spacecraft. The plurality of wiring routing 106 is attached between the plurality of payloads 101 and the deployments unit 202. The plurality of wiring routing 106 is embodied in an inverted U-shaped profile.

Referring to Figure 2A-2F, the deployment unit 202 comprises a plurality of hinges 203 and a plurality of transmission members 104 (as shown in Figure 1B). The plurality of hinges 203 is disposed between the plurality of boom segments 102. The plurality of hinges 203 is adapted to detachably couple the plurality of boom segments 102 with each other from ends in retracted position. The plurality of hinges 203 comprises a first hinge bracket 204 and a second hinge bracket 205. The first hinge bracket 204 is connected with an end of one of the plurality of boom segments 102. The second hinge bracket 205 is connected with an end of the adjoining boom segment from the plurality of boom segments 102, disposed adjacently and subsequently, to the one of the boom segments from the plurality of boom segments 102.

For example, the first hinge bracket 204 may be connected with an end of the first boom segment 102a (as shown in Figure 1A) and the second hinge bracket 205 may be connected with an end of the first boom segment 102b (as shown in Figure 1B). Similar configuration is provided for remaining boom segments from the plurality of boom segments 102 which is not explained in the present disclosure for sake of brevity. Further, the plurality of hinges 203 is adapted to attach and enable relative motion between each of the plurality of boom segments 102 disposed adjacently and subsequently with each other. The each of the plurality of boom segments 102 are attached with each other through the plurality of hinges 203 in a manner that each of the plurality of boom segments 102 are folded parallel to each other, in the retracted position or in the stowed condition. Also, each of the plurality

of boom segments 102 is collinear with respect to each other, in the extended condition. Further, the plurality of boom segments 102 is driven by an elastic member 207 of the deployable boom assembly 100.

Further, the plurality of transmission members 104 are supported on the plurality of hinges 203. More precisely, the plurality of transmission members 104 is disposed at the bottom side of the plurality of hinges 203 in a manner that each of the plurality of transmission members 104 has a driver portion 209a and a driven portion 209b. The plurality of transmission members 104 are movably disposed between the plurality of boom segments 102. Each of the plurality of transmission members 104 is adapted to be driven by one of the plurality of boom segments 102 and is adapted to drive adjoining boom segment from the plurality of boom segments 102. The adjoining boom segment is disposed adjacently and subsequently to the one of the plurality of boom segments 102, between the retracted and the extended position.

Further, the plurality of transmission members 104 is installed in such a manner that the plurality of wiring routing 106 and plurality of wiring routing 105 is routed with the plurality of transmission members 104. The plurality of wiring routing 106 is attached between the plurality of payloads 101 and the plurality of transmission member 104 of the deployment unit 202. The wiring routing 106 is routed at one side of the plurality of boom segments 102. This configuration reduces resistive wiring torque in the assembly, avoids curling twisting of the wire, and can withstand extreme thermovac condition. Further, the plurality of wire routing 105 (as shown in Figure 1B) is routed through the driver portion 209a and the driven portion 209b of the plurality of transmission members 104 through different mechanism, for example, a wire rope pulley mechanism. The plurality of wire routing 105 is routed through the driver portion 209a and the driven portion 209b of the plurality of transmission members 104, where the wires from the plurality of wire routing 105 is routed through a groove provided in the driver portion 209a and

the driven portion 209b, respectively. Further, the wires are anchored by different elements, for example, a knot, a tab etc.

The wire routing 105 is routed with a predetermined tension in each of the wire routing of the plurality of wire routing 105. The predetermined tension is provided by the monitoring and correction mechanism 208 of the deployable boom assembly 100. The monitoring and correction mechanism 208 consists of a compression spring and a turnbuckle with a threaded lead. This mechanism helps in providing the predetermined tension to the wire routing 105 by means of measuring a compressed length of a compression spring. Further, a plurality of guide pulleys 210 is provided to guide the wire routing 105. This configuration ensures reduced friction torque on the plurality of hinges 203 and also eliminates interference of the wire routing 105 with surrounding components and also helps in ensuring simple wire routing 105.

More precisely, in one implementation, each transmission member 104a, 104b, 104c, 104d, 104e (as shown in Figure 1B) of the plurality of transmission members 104 has the driver portion and the driven portion. Further, constructional, and operational aspect of the driver portion and the driven portion of each transmission member 104a, 104b, 104c, 104d and 104e is same as the driver portion 209a and a driven portion 209b of the plurality of transmission member 104. In view of the same, the wire routing 105a from the plurality of wire routing 105 is routed through a root transmission member 104a to the driven portion of the transmission member 104b (as shown in Figure 1B), where the root transmission member 104a is attached with the spacecraft. Further, the root transmission member 104a has a diameter twice the diameter of each of the adjoining transmission members 104b, 104c, 104d and 104e. The wire routing 105b from the plurality of wire routing 105 is routed through the driver portion of the transmission member 104b to the driven portion of the transmission member 104c (as shown in Figure 1B).

Further, the wire routing 105c is routed through the driver portion of the transmission member 104c to the driven portion of the transmission member 104d (as shown in Figure 1B). Similarly, the wire routing 105d from the plurality of wire routing 105 is routed through the driver portion of the transmission member 104d to the driven portion of the transmission member 104e (as shown in Figure 1B). The wire routing 105 includes a space graded material, for example, a kevlar wire. This configuration ensures a closed loop assembly where each of the transmission member 104a, 104b, 104c, 104d, 104e has the driver portion and the driven portion through which the plurality of wire routing 105 is routed. This configuration ensures that energy is distributed along each wire routing 105a, 105b, 105c, 105d routed to connect the plurality of boom segments 102 with each other. This configuration ensures attachment of each of the plurality of boom segments 102 with each other with reduced number of components and withstand launch loads and thermal gradients. This configuration also ensures a simple compact structure with simple wire routing of the deployable boom assembly 100. This configuration also ensues compact packaging of the deployable boom assembly 100 by storing/folding the plurality boom segments 102 over one another in stowed condition/retracted condition

Further, at time of deployment, each of the boom segments 102a, 102b, 102c, 102d, 102e, having the plurality of payloads 101, is driven by the elastic member 207. Specifically, as the plurality of transmission members 104 are installed at the ends of the plurality of boom segments 102, thus, folding directions of the plurality of transmission members 104 changes, therefore, direction of working of the plurality of transmission members 104 are also in opposite direction. Hence, for instance, the transmission member 104a works in clockwise direction and subsequently in anticlockwise direction.

The plurality of transmission member 104 and the plurality of wire routing 105 enable the plurality of boom segments 102 to retract and extend in a coordinated manner, where the plurality of boom segments 102 is locked by the lock and pawl

mechanism 206. The pawl rides over a cam surface of the plurality of hinges 293, in the stowed condition. Further, in the deployed condition, the pawl 206a latches into a wedge section 211 provided in the cam surface of the plurality of hinges 203 and prevents the hinge from unlocking

Further, the deployable boom assembly 100 in deployed condition forms a stable platform of 6 meter to place the plurality of payloads 101 away from the spacecraft. The plurality of wire routing 105 routed through the the driver portion 209a and the driven portion 209b of the plurality of transmission member 104 extends and retract the plurality of boom segments 102 in a predetermined angle θ between the retracted position and the extended position, where the predetermined angle θ is also coordinated in a manner to ensure coordinated opening of the plurality of boom segments 102. For instance, in deployed condition, the first boom segment 102a is smaller than the adjoining second boom segment 102b and the diameter of the root transmission member 104a is greater than the diameter of the adjoining boom segments 104b, 104c, 10d, 104e. Thus, the predetermined angle θ between the boom segment 102a and the adjoining boom segment 102b, disposed adjacently and subsequently with respect to the boom segment 102b, is in ratio of 1:2.

Similarly, the predetermined angle θ between the boom segment 102b and the adjoining boom segments 102c, 102d, 102e, disposed adjacently and subsequently with respect to the second boom segment 102b, is in ratio of 1:1. This configuration ensures that the first boom segment 102a has to travel, for example, 90 degree during deploying the plurality of boom segment 102 and the adjoining boom segments 12b, 102c, 102d, 102e travels, for example, 180 degree for during deploying the plurality of boom segment 102. This configuration ensures that the boom segments open in coordinated manner leading to an accordion set of openings of the plurality of boom segments 102 without any need/requirement of additional component, for example, motor, thus maintaining, efficiency of the deployable boom assembly 100.

As would be gathered, the deployable boom assembly 100 with the plurality of wire routing 105 and the plurality of transmission member 104 of the deployment unit 202 of the present disclosure ensures deployment of the plurality of boom segments 102 with reduced number of components as the wire routing 105 routed from the driver portion 209a and the driven portion 209b of each of the transmission members 104 enables extension and retraction of the plurality of boom segments 102.

Further, the plurality of wire routing 105 routed through the driver portion 209a and the driven portion 209b of the plurality of transmission member 104 also ensures compact stowing of the deployable boom assembly 100 and also, transfer and withstand the launch loads and fit into a launcher envelope. Further, the energy is equally distributed to each of the wire of the plurality of wire routing 105, thus maintaining the efficiency of the deployable boom assembly 100 while ensuring life of each of the wire of the plurality of wiring routing 105. Also, the present configuration ensures coordinated opening of the plurality of boom segments 102 for deploying the plurality of payloads 101 in the orbit, without usage of motor unlike as the known art. This also reduces deployment latch up shocks and provide for easier ground testing conditions. Further, the plurality of payloads 101 is installed at a predetermined distance on the magnetically clean plurality of boom segments 102, ensuring efficiency of the plurality of payloads 101. The configuration of plurality of wiring routing 106 routed between the plurality of payloads 101 and the plurality of transmission members 104 reduces resistive torque of the wire. The present configuration also ensures locking of the deployable boom mechanism 100 with the lock and pawl mechanism 208, where telemetry indication is provided by means of micro switches and contact switches.

While specific language has been used to describe the present disclosure, any limitations arising on account thereto, are not intended. As would be apparent to a person in the art, various working modifications may be made to the method in

order to implement the inventive concept as taught herein. The drawings and the foregoing description give examples of embodiments. Those skilled in the art will appreciate that one or more of the described elements may well be combined into a single functional element. Alternatively, certain elements may be split into multiple functional elements. Elements from one embodiment may be added to another embodiment.